LQ search in e□jj channel

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-Blessing-

Introduction

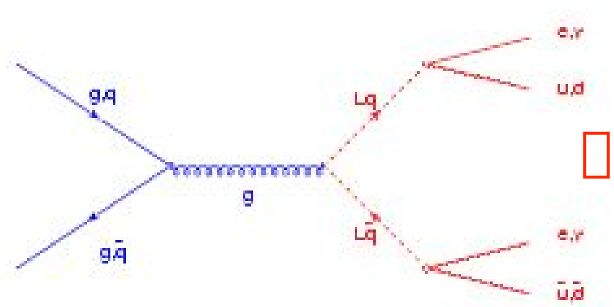
- This analysis is an update of the result produced in June 2003
- REMAKE data 4.11.1 up to Summer shutdown used - 203 pb^{-1}
- New treatment of efficiencies
  - ID efficiencies used in MC and scaled to data
- New good run list
- Revised final selection cut
  - New MET cut raised at 60 GeV
  - New cut around the nominal LQ mass

Issues from pre-blessing

- More Plots
- Mass cut - checking alternative combinations
- QCD background
- Systematics (pdf)

LQ production at the TeVatron

- Production
  - qg → LQ + LQbar
  - gg → LQ + LQbar
  - qqbar → LQ + LQbar



β = Br(LQ->eq)

- Decay
  - LQLQ → l^+l^-qq, $l^\pm$νqq, ννqq
- Experimental signature:
  - High pt isolated leptons (and/or MET) + jets

M_{LQ} (GeV/c^2)	σ(NLO) [pb]
200	0.265E+00
220	0.139E+00
240	0.749E-01
260	0.412E-01
280	0.229E-01
300	0.129E-01
320	0.727E-02

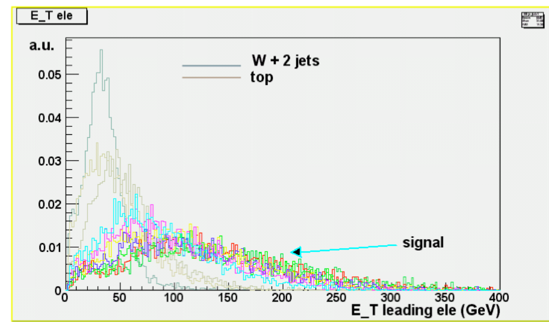
In this analysis: e ν + 2 jets

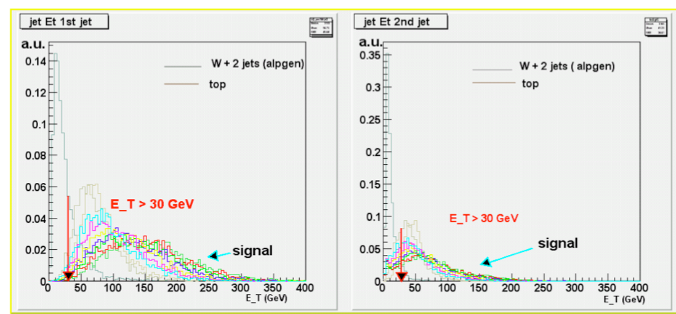
LQ search in $e\nu jj$

Signature: 1 electron, 2 jets and large MET

Analysis cuts

- 1central electrons with E_T > 25 GeV
- MET > 60 GeV
- Veto on 2nd electron, central loose or Plug
- 2 jets with E_T > 30 GeV
- $\Delta\phi$ (MET-jet) > 10°
- E_T(j1) + E_T(j2) > 80 GeV
- $M_T(e-\nu)$ > 120
- LQ mass combinations





Events with 2 central/plug electrons are rejected (to be orthogonal to eejj analysis)

Tools

- Signal generated and reprocessed with 4.9.1
  - 5000 events at masses from 100 to 280
    - run number 151435
    - full beam position
      - talk GenPrimVert
      - BeamlineFromDB set false
      - sigma_x set 0.0025
      - sigma_y set 0.0025
      - sigma_z set 28.0
      - pv_central_x set -0.064
      - pv_central_y set 0.310
      - pv_central_z set 2.5
      - pv_slope_dxdz set -0.00021
      - pv_slope_dydz set 0.00031
      - exit
- eN (4.9.1)used for ntuple analysis
  - http://ncdf70.fnal.gov:8001/talks/eN/eN.html

Efficiencies & acceptance

$$\varepsilon_{tot} = \varepsilon_{Acc}(M) \times \varepsilon^{data}_{ID} / \varepsilon^{MC}_{ID} \times \varepsilon_{z0} \times \varepsilon_{trig}$$

- Trigger
  - Top/EW - we use 0.961 ± 0.005
- Efficiencies for electron selection cuts
  - Z′ analysis : one tight electron

    ε_T = 94.5 ± 0.2 %
- Other
  - eff. on the vertex cut ($|z_0| < 60$ cm) 95.2 ± 0.1 (stat) ± 0.5 (sys)

Kinematical and geometrical acceptance

- Events are selected where the electron satisfies the tight requirements of the exotic group. The analysis (kinematical) cuts are then applied.

Central electron tight

- $E_t \geq 25$ GeV
- $p_t > 15$ GeV
- hadem <= 0.055 + 0.00045 * E
- E/p < 4 (for $E_T < 100$ GeV)
- iso4e/emet < 0.1
- |DeltaX | < 3.0
- | DeltaZ | < 5.0 cm
- Fiducial = 1
- lshr < 0.2

HEPG electrons are then matched in a □R = (□□^{2} - □□^{2}) cone to the reconstructed electron :

ID efficiencies are calculated on them scale factor to data is derived: □^{data}/□^{MC}

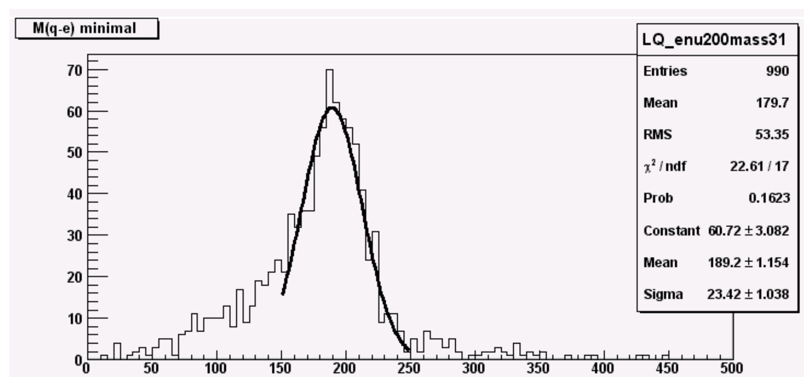
the events surviving the final kinematical cuts are normalized to the number of matching electrons;

Mass Cut

The invariant mass of the electron-jet system and the transverse mass of the neutrino-jet system are selected where the jet assignment is made such that the difference between the electron-jet mass and the neutrino-jet transverse mass is minimized.

The peak of the *ej* histogram is fitted with a gaussian

rough estimate of the spread of the distribution in the signal region.



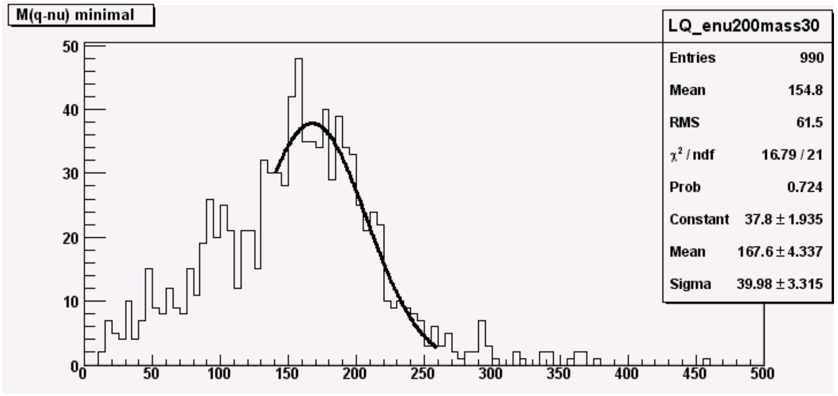
Several masses (120-160-200-240-280) tested:

σ_e ~ 15%.

3σ_e cut around the nominal mass to select LQ candidates of a given mass.

Mass Cut (continued)

The □-*q* transverse mass distribution is fitted including the high mass tail end, with a Gaussian to estimate the signal spread. □□ ~ 25%.



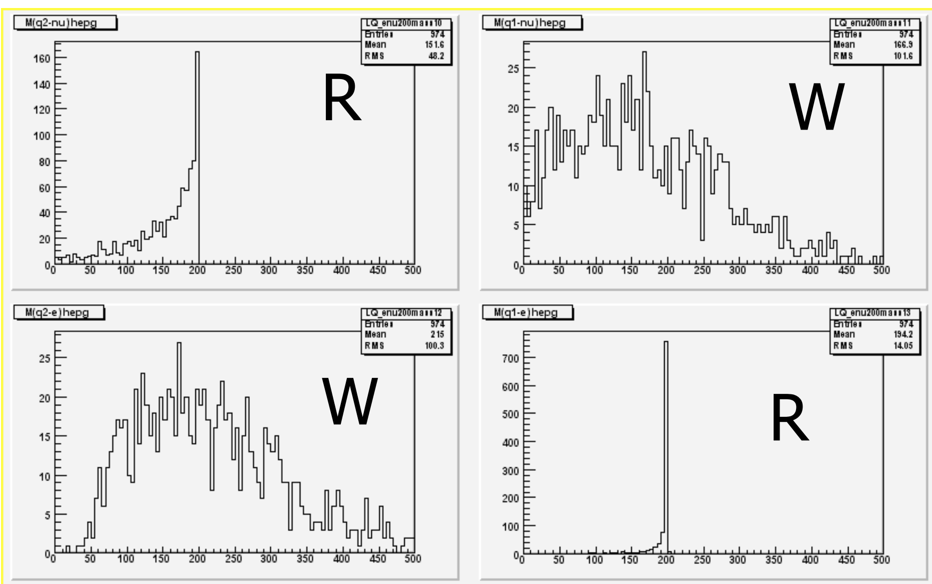
3□□ cut applied around the nominal mass

Mass Cut issues

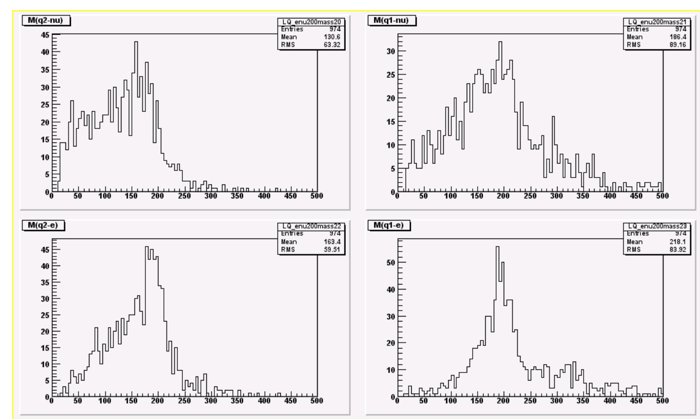
How many times the combination picked is the right one?
Tested on several masses: 75%

Is this number too low? Transverse mass has a large tail already at HEPG level

80-20%



Reco - no *a priori* knowledge



Mass cut issues

We tested other methods in order to evaluate S/B:

1) Both combinations (Cut2)

2) The combination where the objects are most back to back (Cut3)

LQ mass region	Cut1	Cut2	Cut3	W+2 jets Cut1	W+2 jets Cut2	W+2 jets Cut3	Top Cut1	Top Cut2	Top Cut3
m(LQ) =160	11.7	13.5	9.7	2.5	2.5	4.0	2.6	3.8	1.8
m(LQ) = 200	4.46	5.2	3.9	2.5	3.0	4.0	1.8	3.4	1.2
m(LQ) =240	1.6	1.9	1.5	2.0	2.5	3.0	1.0	2.8	0.5

Mass cut issue (cont'd)

S/B is best for the original choice (also chosen in Run I)

We decide to keep using this mass window definition

<u>A comment on □□ of decay products of LQ (E.Perez):</u>

One would naively expect that the □□ distributions of the decay products of the LQ would be back to back.
In reality the □□ distributions are quite distorted due to the large P_T boost the LQ gets. Indeed the LQs are produced with a significant P_T.
This is because they are *scalar* particles

```
               |
q   ------->---- ------<---  qbar    Jz = ± 1 along this axis
               |                (L quark + R antiquark,
               |                 or vice-versa)
```

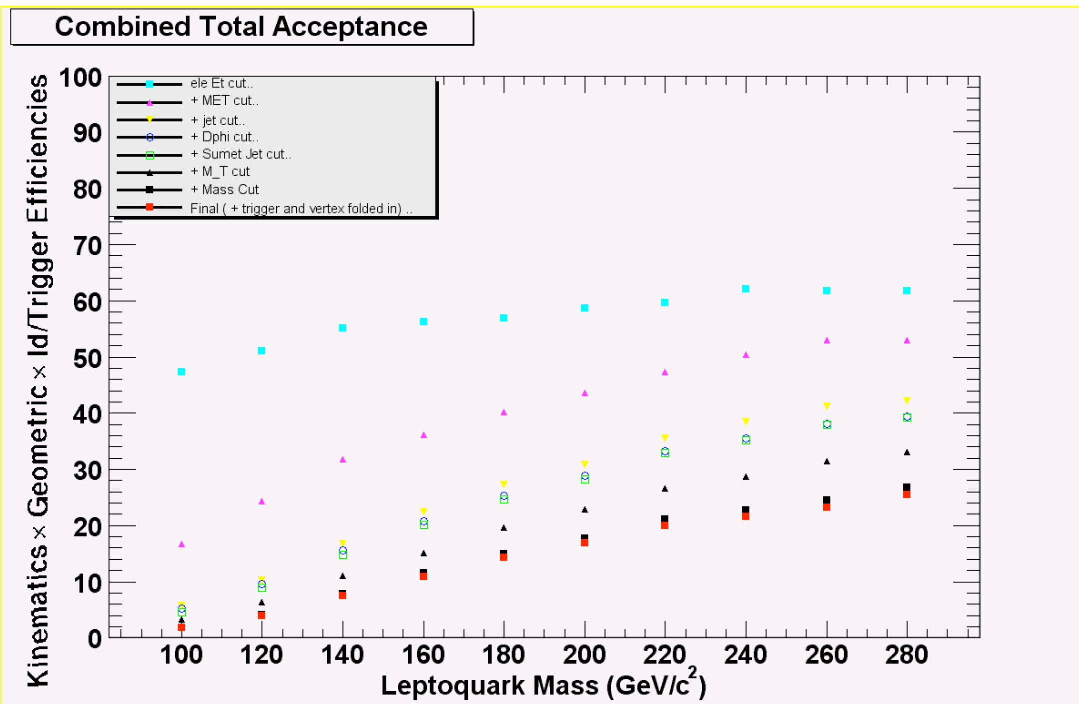
J_z = 0 in the final state since the LQs are both scalars.

Hence to conserve the J_z the prefered outcoming direction for the LQs (in the qqbar c.o.m) is perpendicular to the q-qbar direction. □* peaks at 90 degrees and the P_T's of the LQs are quite large. (the exact pt distribution depending on the distribution of (s-hat))

ttbar is not the same because of the 1/2 spin of the tops.

Final Signal Expected

Number of expected events in 203 pb^{-1}



Mass	σ Theory CTEQ4M (pb)		
	$Q^2 = M^2/4$	$Q^2 = M^2$	$Q2 = 4M^2$
100	31	28	24.1
120	25	22.6	19.5
140	19.7	17.9	15.5
160	13.5	11.7	10.3
180	8.5	7.4	6.5
200	5.2	4.4	3.9
220	3.2	2.7	2.4
240	1.65	1.6	1.4
260	1.11	0.94	0.8
280	0.7	0.6	0.5

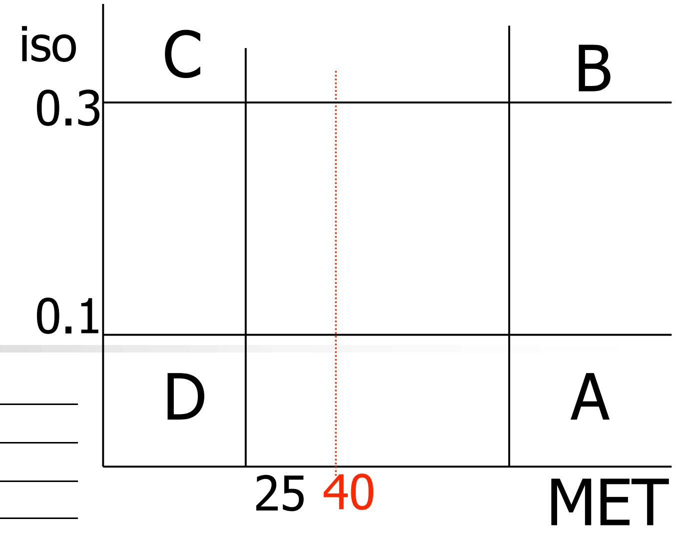
Backgrounds

Main background sources:
W + 2 jets
Z + 2 jets w/ mismeasured electron
Top
W(□ □□) + 2 jets - negligible

MC Alpgen
Pythia

atop02
atop2e
ttopei

QCD fakes - from data iso vs MET negligible



QCD background

Cut	A	B	C	D
lepton	1073	11	17863	71473
2 jets	125	2	578	1489
□□	104	2	474	1207
M_T	18	0	0	1

$E_T^{ele} > 25$

Cut	A	B	C	D
lepton	1252	11	32323	129500
2 jets	143	2	791	1761
□□	122	2	647	1444
M_T	18	0	0	1

$E_T^{ele} > 20$

Cut	A	B	C	D
lepton	1073	11	18989	156995
2 jets	125	2	657	2191
□□	104	2	527	1757
M_T	18	0	1	42

$E_T^{ele} > 25$

C) MET < 40 iso > 0.3
D) MET < 40 iso < 0.1

Decided to consider it negligible

Data sample

- btop0g (inclusive electrons) stripped from bhel08 and (4.8.4 Production)
- Inclusive-ele_4.11.1_REMAKE
- events selected from Ele_18 && Ele_70 triggers
- good runs from March 2002 to September 2003 (141544 - 168889)
  - Good run list from DQM page, em_noSi version 4
    - Removed 4 runs due to CSL problem
    - Luminosity = 199.7 * 1.019 = 203.5 ±12.2
    - http://www-cdf.fnal.gov/internal/dqm/goodrun/v4/goodv4.html

W cross section

$\not{E}_T > 25$ GeV

Relaxing the MET cut to 25 GeV we obtain 112384 candidate W events

We use the same numbers used CDF6681 (the background is scaled to the increased Luminosity) :

$$\sigma \cdot B(p\bar{p} \rightarrow W \rightarrow e\nu) = \frac{N_W - N_{BG}}{A_W \cdot \epsilon(Z_{vtx} < 60) \cdot \epsilon_c \cdot \epsilon_T \cdot \mathrm{R}_{COT} \cdot \mathrm{R}_{EMC} \cdot \int \mathcal{L}dt}$$

$$\begin{aligned}
N_{BG} &= 1656 \pm 52(stat) \pm 295(syst) \\
A_W &= (23.895 \pm 0.03(stat)^{+0.34}_{-0.39}(syst))\% \\
\epsilon(Z_{vtx} < 60) &= (95.0 \pm 0.2(stat) \pm 0.3(syst))\% \\
\epsilon_c &= (81.8 \pm 0.8(stat) \pm 0.2(syst))\% \\
\epsilon_T &= (96.6 \pm 0.1(stat))\% \\
R_{COT} &= (100.0 \pm 0.4)\% \\
R_{EMC} &= (99.8 \pm 0.4)\%
\end{aligned}$$

$N_W = 112384$
$N_{BG} = 1656 * 203/72$
$\int \mathcal{L}dt = 203$

$\sigma = 2.953 \pm 0.032_{stat} \pm 0.051_{sys} \pm 0.177_{lumi}$ nb

W cross section (cont'd)

We checked that we would get the
Same acceptance using W MC:
wewk9e (official EW group)

Acc = 0.213592 ± 0.0013 94.5/89.8 = 22.4 ± 0.002

Our electron cuts are different: E/P in particular is relaxed
Running w/ E/P tightened gives 107385 evts observed

$\boxed{\sigma = 2.816 \pm 0.031_{stat} \pm 0.049_{sys} \pm 0.168_{lumi}\ \text{nb}}$

W + 2 jets cross check

$\not{E}_T > 35$ GeV

We checked the number of events we would expect after the 2 jets cut:

QCD background (corrected for sideband contributions) 38.5 ± 6
Top contribution 56 ± 8
Z + 2 jets contribution ~25 ± 3
W   contribution 16.6 ± 2.6

$\boxed{136.5 \pm 20.4}$

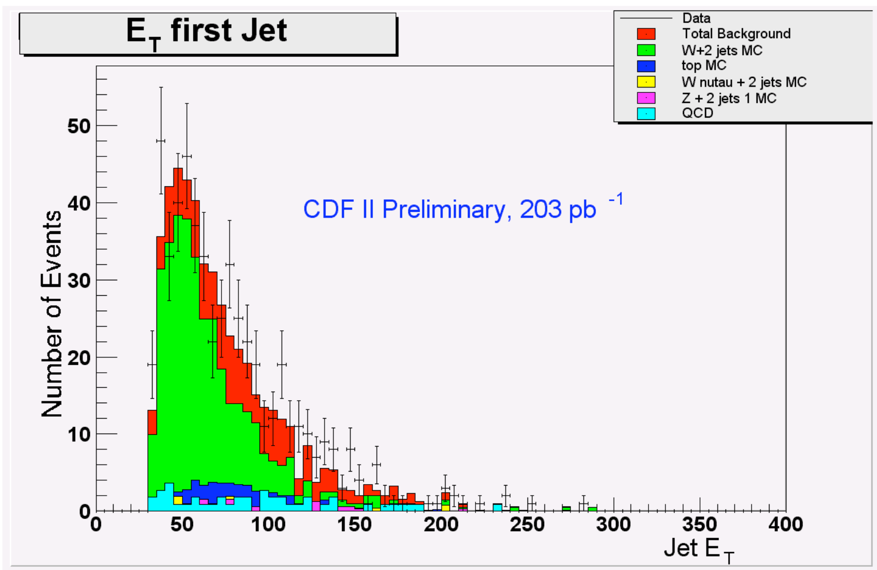
The number of expected W + 2 jets is $\boxed{366 \pm 17}$

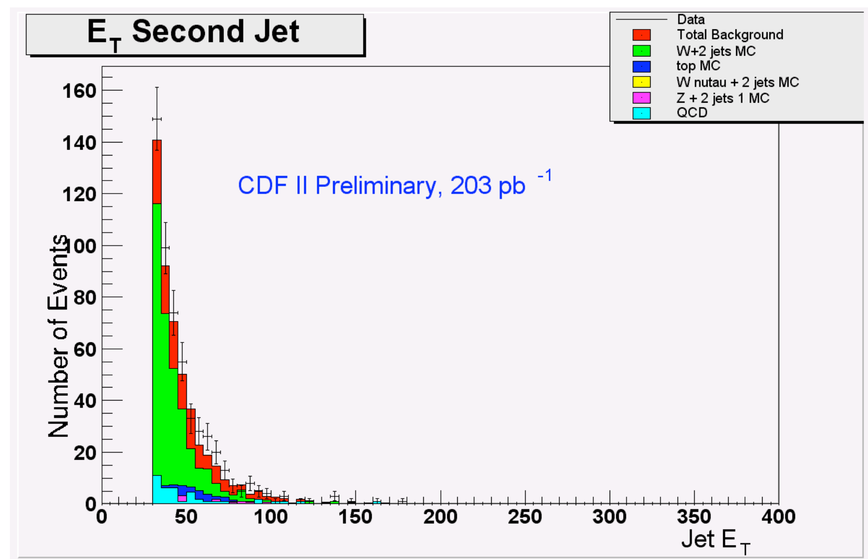
~503

We observe 536 events

W + 2 jets cross check

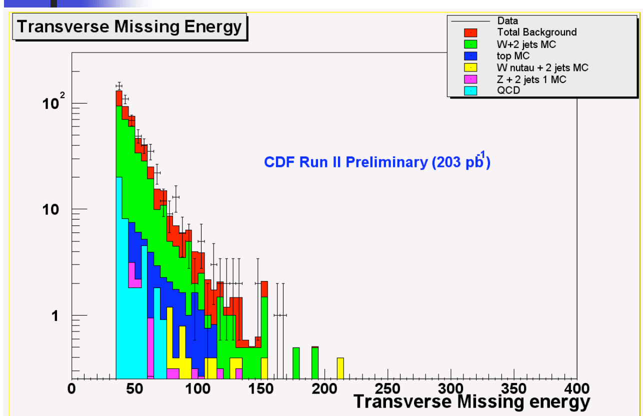
$\not{E}_T > 35$ GeV

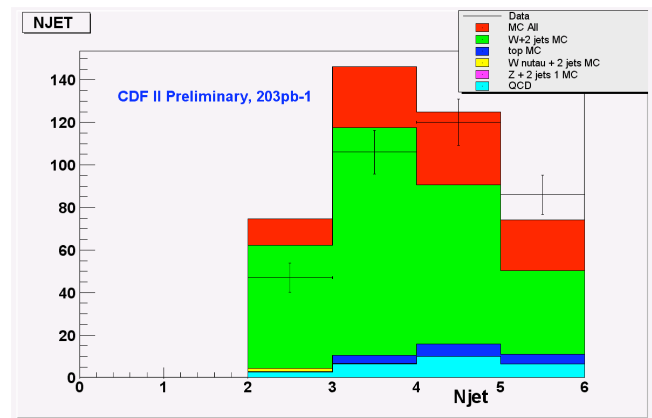


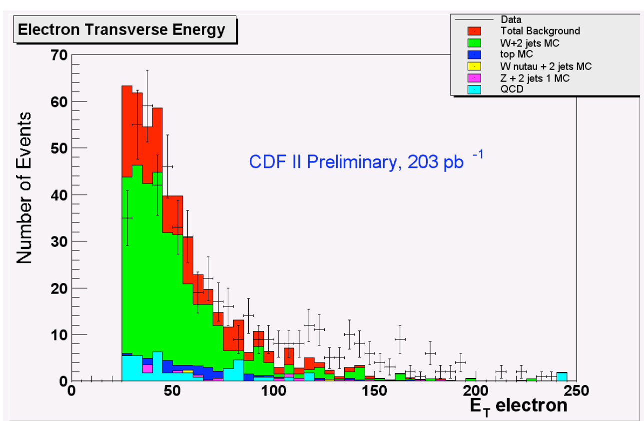


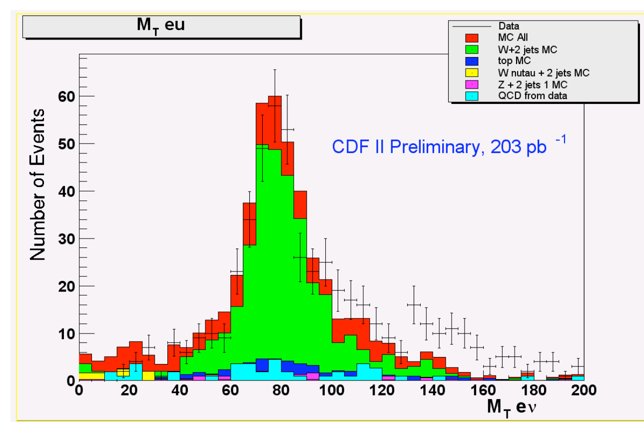
Jet E_T distributions after jets cut

W + 2 jets cross check

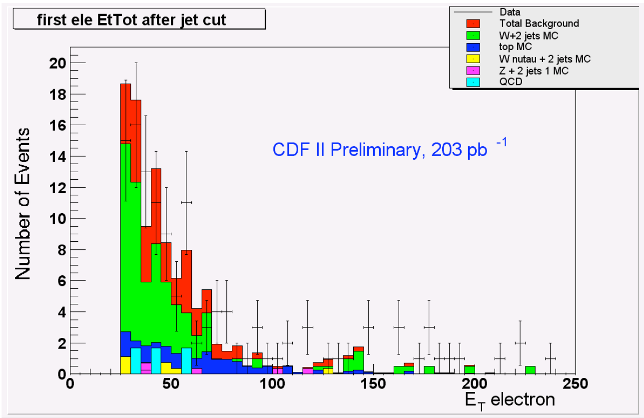




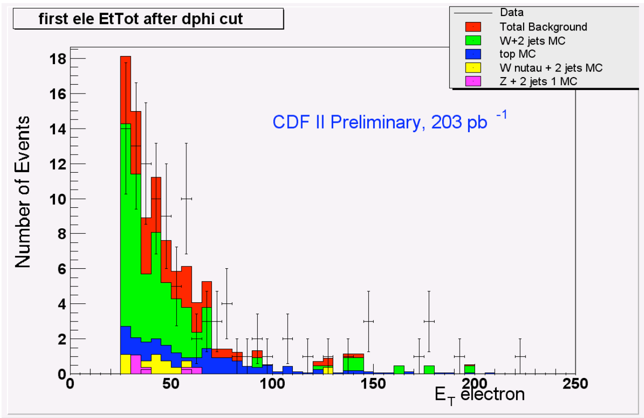




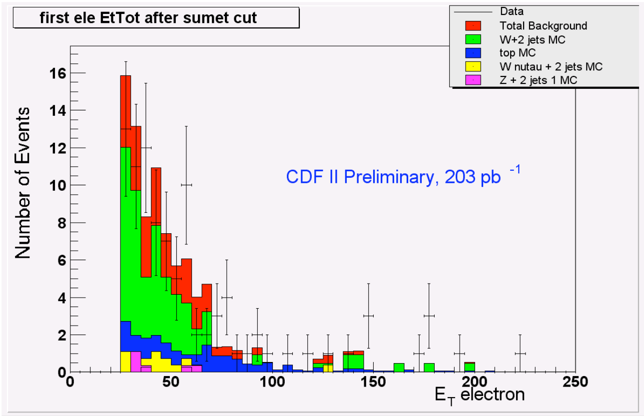
Plots- Met > 60



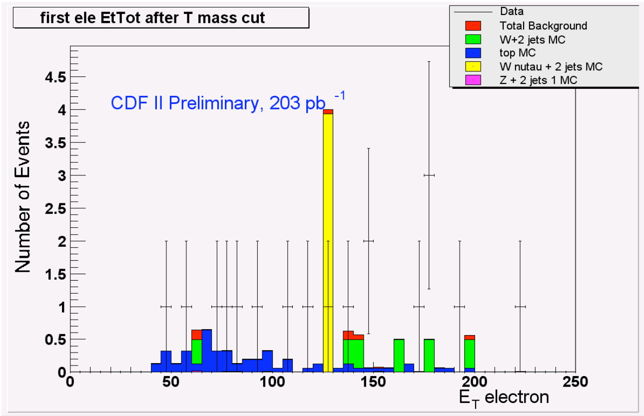
first ele EtTot after jet cut
Data
Total Background
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
QCD
CDF II Preliminary, 203 pb -1
Number of Events
E_T electron



first ele EtTot after dphi cut
Data
Total Background
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
CDF II Preliminary, 203 pb -1
Number of Events
E_T electron

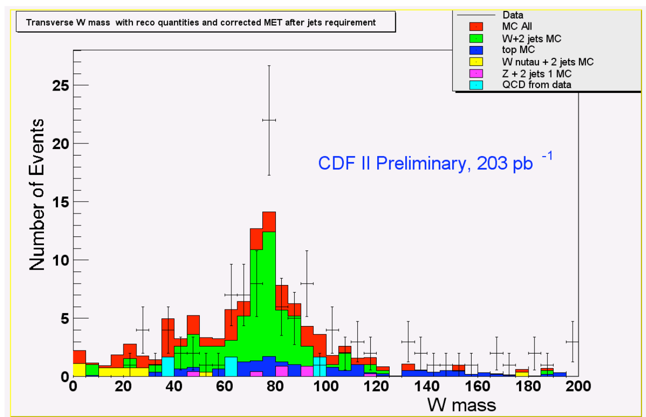


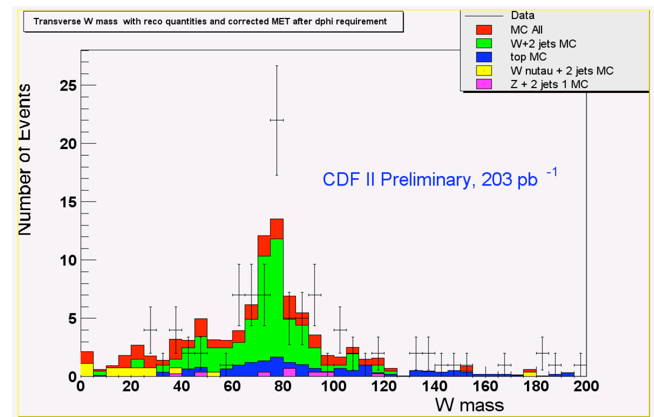
first ele EtTot after sumet cut
Data
Total Background
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
CDF II Preliminary, 203 pb -1
Number of Events
E_T electron

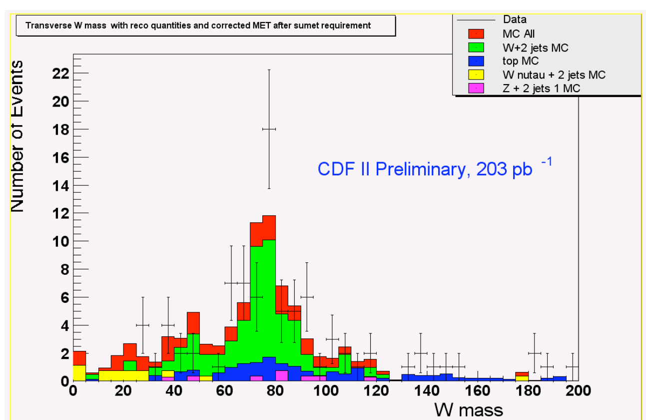


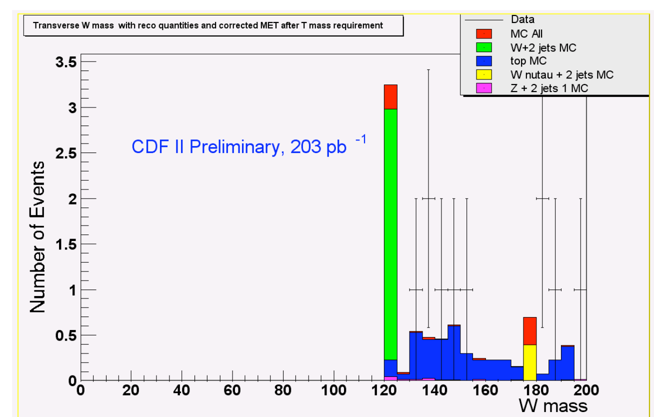
first ele EtTot after T mass cut
Data
Total Background
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
CDF II Preliminary, 203 pb -1
Number of Events
E_T electron

Plots - MET > 60

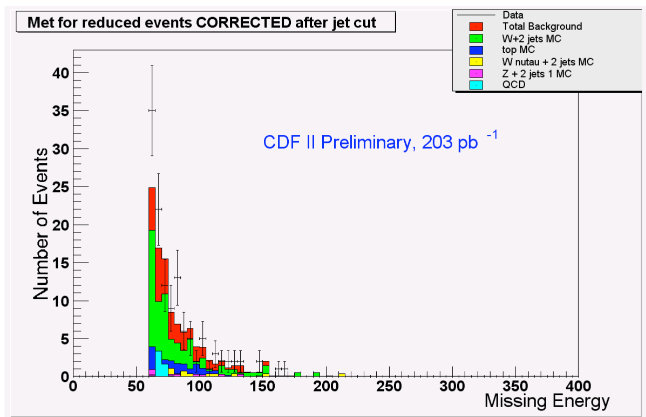

Transverse W mass with reco quantities and corrected MET after jets requirement
Data
MC All
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
QCD from data
CDF II Preliminary, 203 pb -1
Number of Events
W mass


Transverse W mass with reco quantities and corrected MET after dphi requirement
Data
MC All
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
CDF II Preliminary, 203 pb -1
Number of Events
W mass

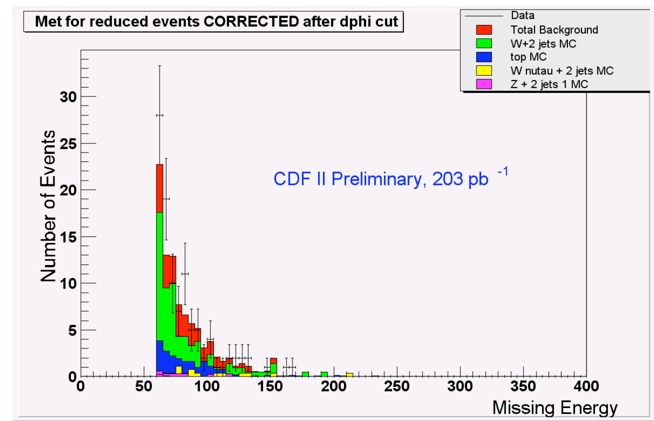

Transverse W mass with reco quantities and corrected MET after sumet requirement
Data
MC All
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
CDF II Preliminary, 203 pb -1
Number of Events
W mass


Transverse W mass with reco quantities and corrected MET after T mass requirement
Data
MC All
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
CDF II Preliminary, 203 pb -1
Number of Events
W mass

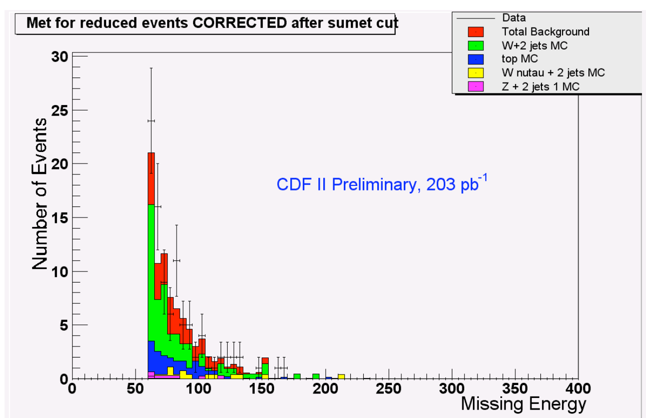
Plots MET > 60



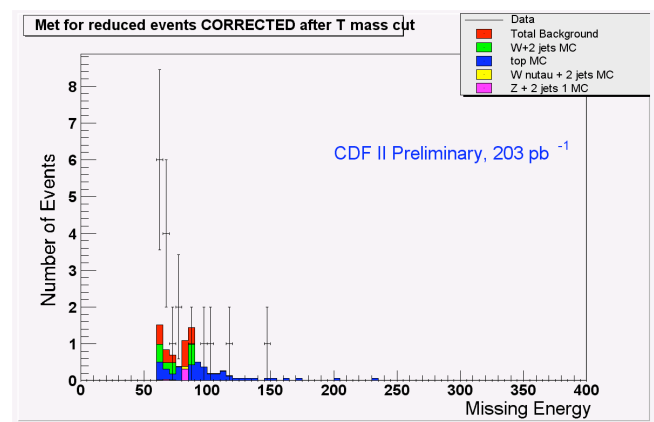
Met for reduced events CORRECTED after jet cut
Data
Total Background
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
QCD
CDF II Preliminary, 203 pb $^{-1}$
Number of Events
Missing Energy



Met for reduced events CORRECTED after dphi cut
Data
Total Background
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
CDF II Preliminary, 203 pb $^{-1}$
Number of Events
Missing Energy



Met for reduced events CORRECTED after sumet cut
Data
Total Background
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
CDF II Preliminary, 203 pb $^{-1}$
Number of Events
Missing Energy



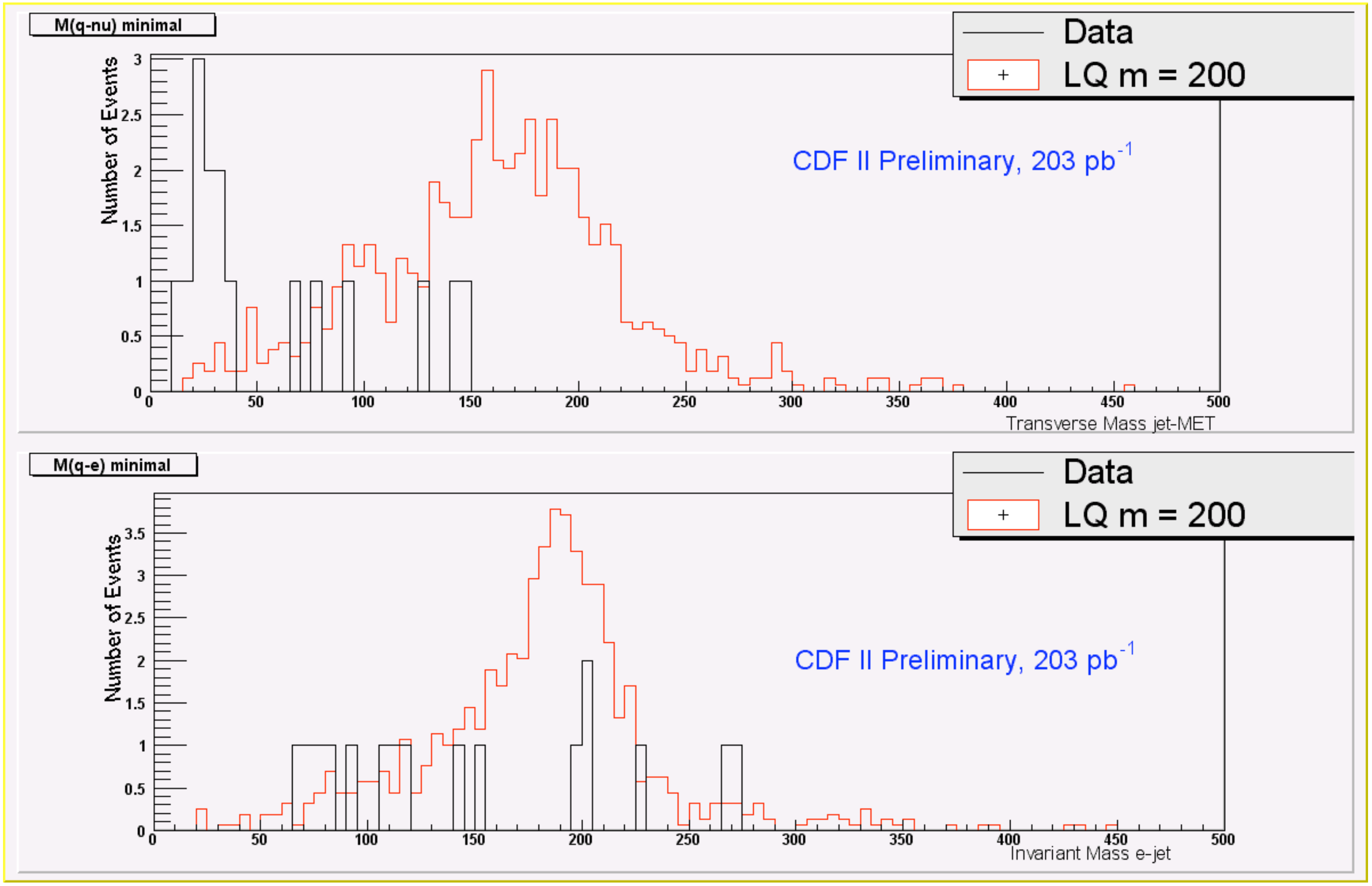
Met for reduced events CORRECTED after T mass cut
Data
Total Background
W+2 jets MC
top MC
W nutau + 2 jets MC
Z + 2 jets 1 MC
CDF II Preliminary, 203 pb $^{-1}$
Number of Events
Missing Energy

Results

events with 1 ele > 25 && MET > 60 1073
events with 1 ele, MET and >= 2 jets (30 30) 125
events with 1 ele, MET and >= 2 jets and dphi cut 104
events with 1 ele, MET and >= 2 jets and dphi cut and 2jet_80 95
events with 1 ele, MET and >= 2 jets and dphi cut and 2jet_80 and T mass cut 18

Mass	100	120	140	160	180	200	220	240	260	280
W+2 jets	1.5±0.9	1.5±0.9	1.5±0.9	2.5±1.13	2.5±1.13	2.5±1.13	2.0±1.0	2.0±1.0	1.5±0.8	0.5±0.4
top	2.5 ±0.6	3.08 ±0.6	2.9 ±0.6	2.6 ±0.6	2.3 ±0.5	1.8 ±0.5	1.5 ±0.3	1.0 ±0.3	0.7 ±0.2	0.6 ±0.2
Z+jets	0.05 ±0.01	0.05±0.01	0.08±0.02	0.08±0.02	0.08±0.02	0.08±0.02	0.06±0.02	0.06±0.02	0.04±0.01	0.04±0.01
Total	4.2±3.8	4.65 ±4.3	4.5 ±4.0	5.16 ±4.3	4.85 ±4.0	4.47 ±3.8	3.6 ±3.2	3.1 ±2.8	2.3 ±2.1	1.1 ±1.1
Data	7	6	4	4	4	4	2	2	2	1

Results



M(q-nu) minimal
Data
LQ m = 200
CDF II Preliminary, 203 pb-1
Number of Events
Transverse Mass jet-MET
M(q-e) minimal
Data
LQ m = 200
CDF II Preliminary, 203 pb-1
Number of Events
Invariant Mass e-jet

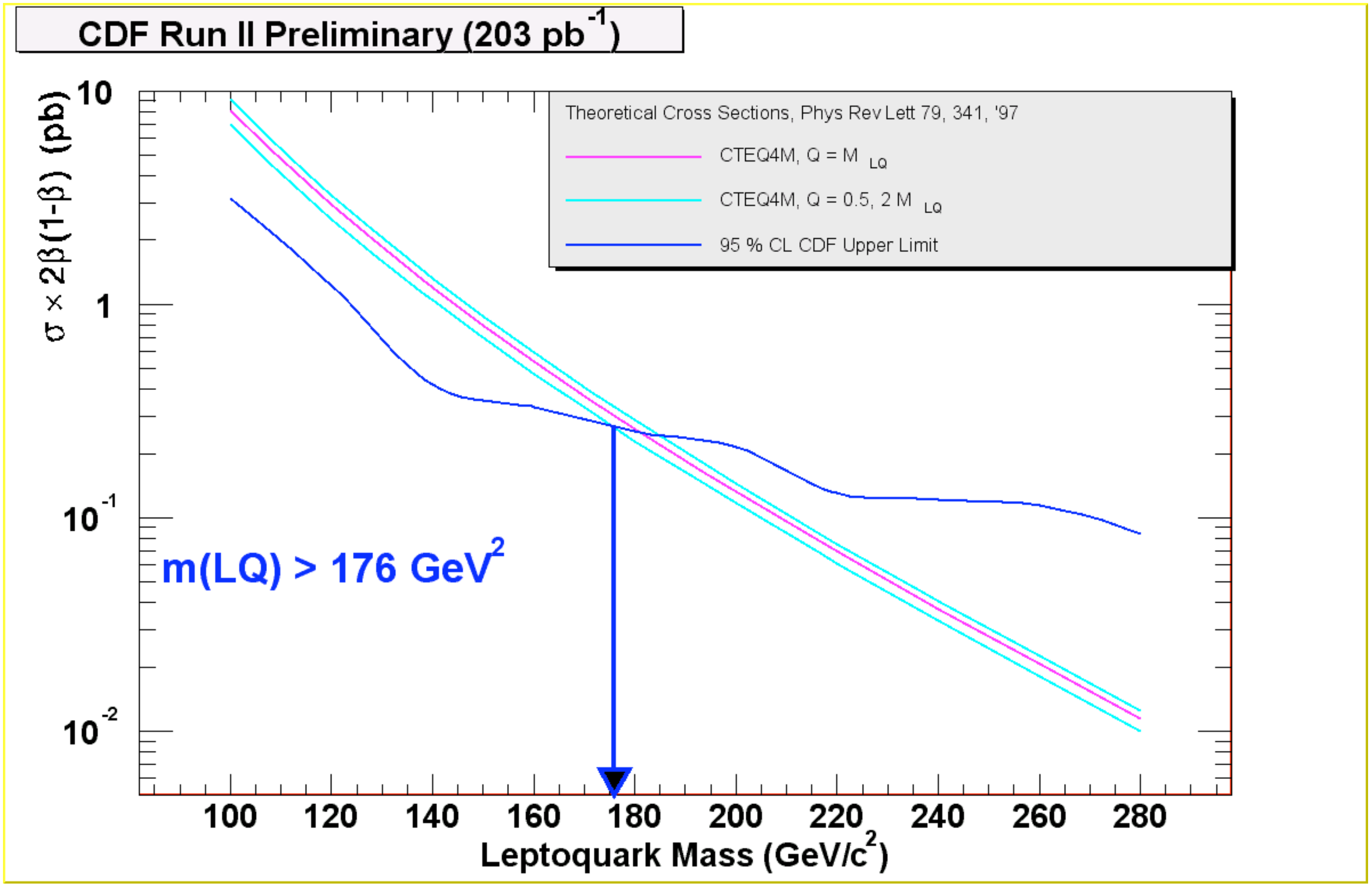
Systematic uncertainties

- Luminosity: 6%
- Acceptance
  - pdf   2.1%
  - statistical error of MC 1.4%
  - jet energy scale (Level 3)
    - jets corrected for energy scale, time dependent and relative response
    - jet energy scaled of systematic uncertainty + 5% (energy scale + 5% data/MC adjustment); 0.4 to 1.0% from mass 100 to 280) 0.6% at 200 GeV/c^2
- Event vertex cut : 0.5%
- ISR/FSR - 1.8%

Final acceptances and errors

Mass	A(LQ)	Stat (Abs)	Sys (Abs)	Total Relative
100	0.017	0.0019	0.001	0.135
120	0.038	0.003	0.003	0.104
140	0.085	0.004	0.006	0.09
160	0.107	0.005	0.008	0.086
180	0.139	0.005	0.010	0.082
200	0.165	0.005	0.012	0.082
220	0.195	0.006	0.014	0.080
240	0.210	0.006	0.016	0.080
260	0.226	0.006	0.168	0.079
280	0.249	0.006	0.018	0.078

Cross section Limit



Conclusions

- A revision of the search for first generation LQ pair decaying into e qq has been performed
  - New data sample - 203 pb-1
  - New final selection cut
  - Revised backgrounds
  - Cross check with W and W + 2 jets cross section
  - limit 176 GeV/c^2

New MET cut

The Missing Et cut has been raised to 60 GeV

Background reduced by a factor ≥2 (top, W + 2 jets)

Signal stays the same

M(LQ)	140	200	280
$E_T > 35$	0.08 ± 0.01	0.17 ± 0.01	0.26 ± 0.006
$E_T > 60$	0.07 ± 0.01	0.16 ± 0.01	0.25 ± 0.006

Top

2.5	3.08	2.9	2.6	2.3	1.8	1.5	1.0	0.7	0.6
4.0	5.0	5.2	4.8	4.2	3.6	3.2	2.2	1.6	1.2

W+ 2 jets

1.5	5.5
1.5	9.5
1.5	9.9
2.5	10.5
2.5	10.
2.5	9.0
2.0	8.0
2.0	7.0
1.5	5.5
0.5	3.5

Other Cuts Efficiency

We studied the effect of 5 cuts on signal (m(LQ) = 200 GeV/c^2) and W + 2 jets and Top (main background)

Analysis of the signal and background reduction by applying all but one cut (N-1)

	Signal	W + 2jets	Top
P_T ele > 25	14.77	16200	113.8
MET > 60 GeV	6.5	22	7.8
2 jets with E_T > 30 GeV	7.8	20.5	6.2
$\Delta\phi$ (MET-jet) > 10°	6.2	5	5.3
$E_T(j1) + E_T(j2)$ > 80 GeV	5.9	3.5	5.0
$M_T(e-\nu)$ > 120	7.1	64.5	22.06
After all cuts in sequence	5.8	3.0	4.82

Acceptances - numbers

Cuts	Cdf 6746	W + 2 jets	m(LQ) = 200
Iso < 0.1	97.2 ±0.2	95.7 ±0.2	95.7 ±0.2
Had/EM	99.0 ±0.1	99.9 ±0.2	99.5 ±0.2
E/P	99.0 ±0.1	97.29 ±0.2	96.8 ±0.2
Dx	98.9 ±0.1	98.9 ±0.2	98.4 ±0.2
Dz	99.7 ±0.1	99.3 ±0.2	98.9 ±0.2
lshr	98.7 ±0.1	98.6 ±0.2	98.9 ±0.2
$\square_T$	94.5 ±0.2	89.9 ±0.2	88.1 ±0.2

Efficiency of the ID cuts for central electrons - individual cuts

MetSig Cut Removal

The E_T significance cut is not optimal:

- large systematic associated due to mis-modeling of Sumet in MC
- Sumet is generally smaller in MC
  - "overefficiency" in MC : for the same MET, Metsig is smaller in data

Mass Cut is used instead of Missing Et significance

- It was used in Run I
- Signal efficiency acceptable (same as Metsig cut)
- Powerful background constrain, better controlled as function of LQ mass
  - BETTER LIMIT !

Mass cut issues (con'td)

We have also checked the mass cut applied in the Run I □□ jj analysis (which Dan will use)

- $|M(\mu j_1) - M_{LQ}| < 2\sigma_1$ **OR** $|M(\mu j_2) - M_{LQ}| < 2\sigma_2$
- $M^T(\not{E}_T j_1) > T_1^{\min}$ **OR** $M^T(\not{E}_T j_2) > T_2^{\min}$

LQ mass region	signal	W+2 jets	Top
M(LQ) = 160	11.7 vs	2.0 vs 2.5	2.6 vs 3.2
M(LQ) = 200	4.5 vs 4.8	2.5 vs 5.5	1.8 vs 2.4
M(LQ) = 240	1.6	2.5 vs 9.0	1.0 vs 1.2